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Foreign Military Sales
Manpower Projection Methodology

TEST AND VALIDATION OF
ALTERNATIVE METHODOLOGIES

STUDY DOCUMENTATION REPORT

Volume I — Results

September 1980

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MANAGEMENT SYSTEMS DIVISION

GENERAL
RESEARCH CORPORATION

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During the period March–September 1980, the General Research Corporation (GRC) tested a wide variety of statistical methods for projecting Foreign Military Sales programs and forecasting manpower requirements in future years. This two-volume report summarizes the test and validation activities, provides the principal results, and recommends further test and validations to be performed before the final selection of methodologies.

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SECTION 1

INTRODUCTION

1.1 GENERAL

This is the third formal report of the General Research Corporation (GRC) on the "Foreign Military Sales (FMS) Manpower Projection Methodology" project. This project was undertaken for the Assistant Secretary of Defense (Manpower, Reserve Affairs, and Logistics) beginning in February 1979.

1.2 OBJECTIVE

The objective of this project is to develop a standard methodology for forecasting manpower requirements for foreign military sales. To accomplish this objective, the project encompassed three tasks:

1. Improvement of the current Security Assistance Manpower Accounting System (SAMAS), including the formulation and recommendation of necessary revisions to the SAMAS DoDI (1 Feb-31 May 1979).

2. Development of alternative strategies and methods for forecasting future-year FMS manpower requirements (1 Feb-30 Sep 1979).

3. Development of a detailed system for forecasting future-year FMS manpower requirements, including the testing of alternatives, the selection and development of a preferred methodology, and the preparation of implementing instructions for the Services (20 Feb-31 Dec 1980).

Although this project was intended to be confined to FMS, the same forecasting methodology is equally adaptable to the Military Assistance Program (MAP). Accordingly, the alternative methodologies discussed in this report encompass both FMS and MAP manpower requirements.

1.3 PREVIOUS REPORTS

In the conduct of this project, we have submitted two Study Documentation Reports (SDR):

- Phase I SDR: "Revised SAMAS Instructions" which covered our review, analysis, and findings on the first two SAMAS reports, our recommended revisions to the draft SAMAS DoDI and our suggested modifications to the program element structure for security assistance programs.

- Phase II SDR: "Alternative Methods for Forecasting Security Assistance Manpower" which covered our review, analysis, experimentation, and findings on the availability of useful data and alternative methods for developing program projections and manpower forecasts.

1.4   ORGANIZATION OF THIS REPORT

This report is concerned primarily with Task 3, our testing and evaluation of alternative methods for forecasting security assistance manpower requirements. In Section 2, we describe our activities and methodologies for test and validation. In Section 3, we describe the results of our tests to date. In Section 4, we present our conclusions on completed tests and our recommendations for the test and validation of additional methodologies leading to the selection of preferred methodologies for development and implementation.

1.5   REPORTING CONVENTIONS

In the interest of clarity and simplicity, we have adopted three conventions in nomenclature which are used throughout this report:

- Although the Security Assistance Program includes more activities than just Military Assistance and Foreign Military Sales, security assistance will refer to the combination or aggregation of MAP and FMS in terms of either Sales or Deliveries.

- Although the Military Assistance Program is executed in terms of MAP Orders and Deliveries and the Foreign Military Sales Program is executed in terms of FMS Agreements and Deliveries, security assistance Sales will refer to both MAP Orders and FMS Agreements.

- Although the terms can be and are often used interchangeably, <u>programs</u> will always be <u>projected</u> and <u>manpower</u> will always be <u>forecast</u>.

1.6 OUTSIDE CONSULTANTS

During the course of this project, we have engaged the services of two outside consultants. Both are acknowledged experts in the field of statistical methods of forecasting. Dr. Guisseppi A. Forgionne, Professor of Management Science at the California State Polytechnic University, inventoried, rationalized, and selected specific statistical methods and software packages to be tested. Dr. Irwin Greenberg, Associate Professor of Business Administration at George Mason University, conducted an independent critical analysis of our methodologies and the results attained.

SECTION 2
TEST AND VALIDATION ACTIVITIES

2.1 GENERAL

The contractual plan for Task 3, Test and Analysis of Alternative Forecast Methods, prescribed the following activities:

- Test and validate program projection methodologies
- Test and validate manpower forecast methodologies
- Select and recommend preferred methodologies

2.2 BACKGROUND

In response to Congressional and GAO criticisms and to correct manpower accounting deficiencies, General Research Corporation (GRC) developed and the Department of Defense (DoD) implemented a "Security Assistance Manpower Accounting System (SAMAS)." It provides a standard means for the Military Departments and Defense Agencies to report the numbers of personnel engaged in security assistance activities, the majority being in the Foreign Military Sales (FMS) program.

In an early review of SAMAS,[1] the GAO cited a need for prescribing more systematic and uniform methods for the Military Services to program future FMS manpower requirements. An effective system of forecasting manpower requirements is essential for DoD to obtain the necessary manpower ceiling headroom to discharge security assistance obligations. This project provides for the development and ultimate implementation of such a manpower forecasting system. This report presents the results to date of our test and validation of alternative methodologies.

2.3 RATIONALE

In our earlier research, we had examined the Security Assistance program and tested the historical data available to identify various forecasting methodologies which offered reasonable prospect for utility

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[1]GAO Report FGMDS 78-47, Inadequate Methods Still Used to Account for and Recover Personnel Costs of the Foreign Military Sales Program, July 25, 1978.

and success. Since that report was issued, our continuing review and experimentation have influenced directly the sequence and procedures used in testing and validating those methodologies:

- Manpower forecasting is at least a two-step procedure: a program or workload projection and an associated manpower requirement forecast.

- Country and country group appear to have little value as independent variables for predicting either workload or manpower.

- Commodity and commodity group appear to have great value as independent variables for predicting both workload and manpower and, indeed, the Service and activity which will execute the program.

- Sales volume (in $ by commodity) appears to bear most directly on administrative manpower requirements.

- Deliveries volume (in $ by commodity) appears to bear most directly on direct manpower requirements.

- The MAP component of Security Assistance is small in comparison to the FMS component. The projection methodology should address the whole Security Assistance program and then, the components.
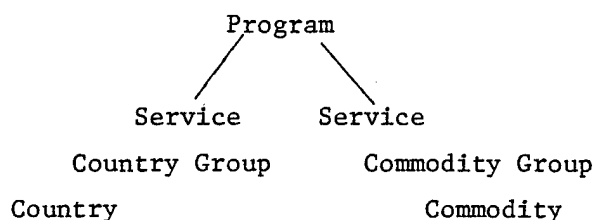
Using these findings, we structured our test and validation task plan to:

- Construct time series and develop forecast equations for sales and deliveries for FMS and MAP (separately and combined):

    (1) Total program
    (2) Service program
    (3) Country group programs[1]
    (4) Commodity group programs

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[1] In spite of the apparent lack of utility as a forecast variable, country group relationships were tested for three reasons: (1) a reluctance to discard any methodology without adequate test; (2) to provide program projections in conformance with the strategic orientations of the Consolidated Guidance; (3) ready availability of data.

- Examine results of test and validation of forecast equations for such anomalies as: atypical countries or country groups; atypical commodities or commodity groups; and atypical Service program years.

- Identify and structure the essential elements of program projection/program guidance by both level and direction of disaggregation:

```
                    Program
                   /       \
                  /         \
            Service         Service
         Country Group     Commodity Group
      Country                  Commodity
```

- Produce all essential elements of program guidance using tested and validated methodologies. Obtain for each method and each projection a coefficient of correlation (or determination) or other measure of accuracy and reliability.

- Construct time series and develop *macro* forecast equations for security assistance manpower, including: sales and deliveries relationships at various levels of program projection; and, manpower estimating equations for sales and deliveries at various levels of program projection.

- Produce *macro* forecast of manpower requirements using tested and validated methodology for various levels of program sales and deliveries projection. Develop the measure of accuracy and reliability.

- Construct a compendium of Service methods for estimating manpower requirements based on workload factors, standards, or measurements to be adopted/adapted for use as *intermediate* forecast methods for various levels of program projection.

- Analyze each method for accuracy and reliability when used by the developing Service for its primary purpose, and for its probable utility value when applied to other uses/users.

- Identify untested or undeveloped methods that might be applied to the security assistance requirement.

- Produce *intermediate* forecasts of manpower requirements using forecast methodologies identified and adopted. Test and validate each methodology for various levels of program projection. Develop measures of accuracy and reliability for each methodology.

- Construct historical life cycle of FMS cases/MAP orders by Service and commodity group. Establish key events in the life cycle and the probabilities and rates at which each event occurs and is completed.

- Establish, from DSAA and Service records, the manpower relationships for each key event and time period in the life cycle. Develop *micro* forecast equations for security assistance manpower.

- Produce *micro* forecast of manpower requirements using tested and validated methodology for projecting the LOR (case/order) life cycle. Develop the measure of accuracy and reliability.

2.4   PROCEDURES

The DSAA 1979 Fiscal Year Series Report provides 30 years (1950-1979) of individual country FMS and MAP dollar sales and deliveries by year. The individual country data were posted and aggregated into country groups corresponding to those used in the Consolidated Guidance. The country group sales programs were then summed to obtain the total dollar value of security assistance (FMS and MAP combined) sales/orders and deliveries over the 30-year period. Total security assistance sales and deliveries data were used to derive a total program forecast equation. The aggregated country group sales and deliveries data were used to derive a forecast equation for sales and deliveries by country group.

The DSAA FMS and MAP data files provide 16 years (1964-1979) of detailed data to form a time series of dollar sales by country group and Service. These data were aggregated by Service and used to develop forecasting equations for dollar sales volume by Service for each country group.

The DSAA FMS and MAP Case and Detail files provide 16 years (1964-1979) of detailed data to form a time series of dollar sales by commodity group and Service. These data were aggregated by Service and commodity group and will be used to develop forecasting equations for dollar sales volume by Service for each commodity group.

The LOR subsystem of the DSAA Case and Detail files provides only 6 years (1975-1980) detailed history data on the life cycle of letters of request. These data are being aggregated and analyzed to develop a model of the LOR process by Service and commodity group.

Using aggregated time series data on sales and deliveries, a relationship between sales and deliveries was derived. Based on the assumption that the manpower requirement would depend on both total dollar sales and total dollar deliveries, a manpower relationship was also developed and tested. These relationships were used to derive a manpower requirements forecast equation -- a *macro* method for manpower forecast.

Using disaggregated time series data on security assistance or its components, by Service, by commodity group, and by country group, we have begun to derive workload and manpower relationships at other levels -- *intermediate* methods for manpower forecast.

Using disaggregated time series data from the LOR subsystem and Service estimates for the administrative manpower for each phase in the life cycle, we will derive life cycle event and manpower relationships for administrative manpower -- a *micro* method for manpower forecast.

2.5 DATA ACCESS AND AVAILABILITY

The Defense Security Assistance Agency (DSAA) maintains a rather comprehensive file of historical data on the security assistance programs (countries, commodities, sales, deliveries, dollars). The Military Services and Defense Agencies also maintain comprehensive files of historical data on Service/Agency conduct of security assistance programs (countries, commodities, sales, deliveries, dollars, and case identity).

There is no historical file of any significance (except SAMAS) which records or accounts for the manpower associated with the security assistance programs.

2.5.1 Data Repositories

2.5.1.1 Defense Security Assistance Agency (DSAA)

DSAA maintains its computerized records for FMS/MAP transactions on an IBM 3033 computer through the Director of OSD Systems, Air Force Data Systems Center, Defense Security System Division in Room 4C653, The Pentagon. GRC was not permitted access to the terminal site located in Room 4C653. In lieu of working with DSAA files on site, DSAA agreed to furnish both hard copy and tapes to GRC for use as discussed below.

The 1979 Fiscal Year Series Report, published by the Data Management Division, Comptroller, DSAA, contains data in dollars for fiscal years 1950-1979 by country group for:

- FMS agreements (or sales)
- FMS deliveries
- MAP program (or orders)
- MAP deliveries

These data were useful to obtain a basic or macro view of security assistance and country groups. Data on country group totals were adjusted to reflect the Consumer Price Index (CPI) and entered manually into the MULTICS system for preliminary analysis. These are the only DSAA data that provide a full 30-year record at the requisite level of disaggregation. Figure 2.1 is a graphic presentation of the 30-year Security Assistance Sales and Deliveries program in constant (FY 67) dollars.
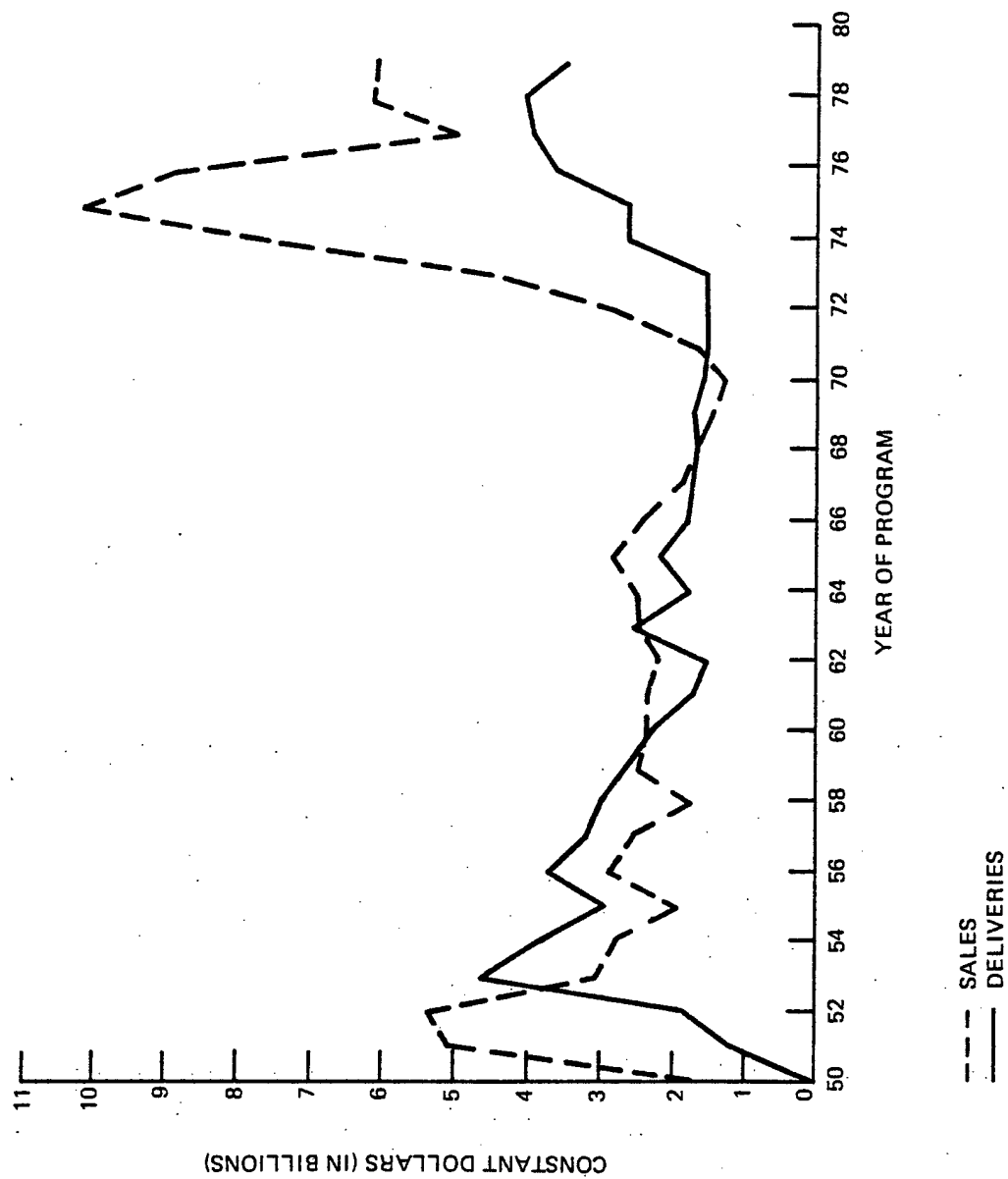
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Figure 2.1 Security Assistance Sales and Deliveries, 1950-1979

DSAA furnished GRC two MAP, two FMS, and one LOA/LOR data tapes.

- Initially, the MAP tapes were unreadable on MULTICS because on a noncompatible computational field. DSAA reran the tapes with the required conversions.

- No problems were encountered with the FMS tapes; however, a problem similar to the MAP problem currently exists within the LOA/LOR tapes.

- Because all data prior to 1964 have been rolled up into a 1963 total, only 16 years (1964-1979) of program data are usable for analysis and forecasting.

- GRC has extracted total dollar sales data for the FMS and MAP programs by year, by country, and by Service.

- GRC has extracted FMS sales and MAP orders and deliveries data by year, by commodity, and by Service.

2.5.1.2 Office, Assistant Secretary of Defense (Manpower, Reserve Affairs and Logistics) [OASD(MRA&L)]

OASD(MRA&L) maintains its computerized records for SAMAS manpower data through the Director of OSD Systems, Air Force Data Systems Center in Room 2D279, The Pentagon. Although this is primarily an OASD(PA&E) MULTICS facility, MRA&L and GRC have access to terminals for the development and maintenance of DoD projects and files. GRC has access to the MULTICS on the MRA&L activity account.

2.5.1.3 Georgetown University

Through a consultant to the project team, GRC has obtained access to the Georgetown University Data Processing Library. Georgetown University has an IBM 370 computer with DAS 360 terminals. This is an excellent facility on which to conduct experimental research, create a data base, and test methodologies. A software system, called TROLL, contains statistical packages well suited to the FMS project. GRC has used the facility extensively since mid-June.

2.5.2 Problems and Solutions

Throughout this phase of the project, constrained access to the data and the data processing facilities has been a major problem.

- In early April, we requested transfer of the DSAA history files to the MULTICS site. The transfer was delayed (until May) awaiting conversion of DSAA data.

- In the interim, we were able to experiment with annual sales and deliveries data by manual input to the MULTICS System. Initial time series plots were made and the Box–Jenkins statistical package was run using these data.

- In late May, GRC lost its computer terminal access until an MRA&L funding account could be established (in June).

- In late May, DSAA data file tapes were made available and retrieval programs were written to read the tapes and extract the useful data.

- During this period, the team was limited to those analyses which could be accomplished using a TI–59 programmable calculator. Our work included: a number of time series analyses of the available data; several least squares fits; and exponential smoothing with several values of damping.

- By mid–June, the team had begun to use the Georgetown University computer facility where our project consultant had access. This facility has terminals linked to an IBM 370 computer and many statistical packages designed for economic and management systems analysis.

- In late June, when MULTICS access was restored, the previously cited computation problems with DSAA furnished tapes were identified.

- During late June and early July, the team again used manual data input to form files of sales and deliveries data. Extensive analysis of those files was accomplished using the Georgetown University computer facility.

- By late July, DSAA-furnished FMS tapes were finally read and extracts produced for analysis on the Georgetown computer. In early August, MAP card decks were produced. Numerous delays were experienced during this data transfer activity. The problems appeared to be anomalies associated with the MULTICS computer/card-punch process.

Even without these problems and delays, the need to analyze such an immense amount of data has presented a difficult and extremely time-consuming task. Using the large disk files and easy-to-use computer programs available at Georgetown, the GRC team has been able to perform experiments and analyses that would have overloaded the available memory space on the MULTICS system.

2.6   METHODOLOGIES

2.6.1 Time Series

Time series describe the occurrence of events over time. The total yearly dollar amounts of FMS and MAP sales and deliveries describe a time series. Each level of aggregation of FMS/MAP sales and deliveries history describes a separate and distinct time series.

Time series models use past history to predict the future by using the derived forecast equation. Time series data are required for a sufficiently long period of time to ensure confidence that any observed trends or cycles are truly part of the data.

When a single time series treats an event which can be described by summing several other time series, all time series must be consistent and interrelated to provide a 100% certain cause and effect relationship. Thus, the sum of all country sales and deliveries must equal the total sales and deliveries no matter how many subordinate levels of aggregation (time series) are examined.

From our extensive tests of many potential forecasting methods, we
have identified equations which permit us to establish a statistical model
to forecast the total dollar sales at any level of aggregation. These
statistical models do not pretend to forecast the individual events which
will cause variations in sales. Rather, they rely on the fact that since
an event with a particular effect has occurred in the past, it is likely
that some event with a similar effect will recur in the future. We have
developed usable techniques to make such forecasts.

2.6.2 Disaggregations

The statements about time series made above hold true no matter
what the aggregation level. However, we have found many differences in
time series characteristics at various levels of disaggregation.

It appears that both the method and the accuracy of the forecast
at each level of aggregation will differ. This may militate against
attempting to forecast sales for a commodity as opposed to the total
commodity group, or for a country as opposed to the total country group.
In fact, aggregation is, in itself, a form of smoothing, and some level
of aggregation is required to design a statistical model. Therefore, we
can develop forecasts as those levels of aggregation which provide con-
sistent and satisfactory results; and we must integrate all forecasts to
assure their overall consistency.

Although time series presentations are used in all cases, the formal
forecasting or projection equations are quite different and, indeed, more
than one form of equation may be used to forecast the same event.[1]

2.6.3 Manpower Relationships

Like the sales-forecasting relationship, manpower forecasting is
also based on two kinds of formulations: cause and effect, and statistical
relationships.

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[1]There are two forms of equations used to describe light diffraction.
One is based on a theory, the other on statistics. Both are correct
and are used at different times, depending on the detail of the problem.

Cause and effect models are usually based on work factors, difficulty indices, and methods of work. They range from rather simple (single variable) productivity models established for repetitive tasks to more complex (multivariate) models which consider the work to be performed, the conditions under which it is performed, and the relationship of the work to other work performed under different conditions.

Statistical models are usually based on the relationships of easily observable quantities to manpower requirements. The quantity is not usually expressed in terms of work units. In every model developed, however, it is necessary to know something about the manpower required and to relate that manpower requirement to a work factor or a statistical quantity. In the present instance:

a.   There are limited data available about the absolute manpower required for FMS and MAP activities. The most reliable data are within the SAMAS system but have been accumulated only for the past 3 years.

b.   There are even less data available about the relationship between the work factors used in productivity models and the work factors involved in the security assistance sales process.

c.   If it can be assumed[1] that security assistance deliveries do not differ from standard deliveries, there are considerable data available to relate security assistance delivery activities to manpower requirements. Yet, the total manpower involved in the delivery activity represents less than half of the total security assistance manpower requirement.

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[1]There is some argument about this within the Army. It is possible that requirements imposed on FMS-MAP stocking and ordering creates a different ratio of productive work for FMS and MAP than for normal service activity.

It is clear that both cause and effect models and statistical models will be required to forecast security assistance manpower requirements and that they may be appropriate to different levels of aggregation. Specifically:

a.   Administrative workload will likely be forecast using both statistical as well as cause and effect models.

b.   Direct workload will likely be forecast using cause and effect models. These models will likely be the same as the models already used to estimate other Service manpower requirements using appropriately derived modifications to reflect the differences between security assistance and "other" (or normal) activities.

It appears that the ongoing test and validation program will provide:

- A statistical model for the macro method of manpower forecasting.

- A combination of cause and effect and statistical models for intermediate methods of manpower forecasting.

- A cause and effect model for the micro method of manpower forecasting.

2.7   MEASURES OF VALIDITY

2.7.1 Data Adequacy

The basic mechanism used to develop macro manpower forecasts is linear regression. Dollar sales and dollar deliveries data obtained from the DSAA data files (or derived from forecasts) are the fundamental bases of the regression (i.e., the independent variables). Manpower data obtained from the SAMAS or other documentation are the dependent variables.

Thus, the development of projections for dollar sales and dollar deliveries is essential to produce a forecast of manpower requirement, and the following discussion focuses on the adequacy of the data to provide those projections.

Thirty years of "adjusted" data for dollar sales and dollar deliveries by country are available within the DSAA Fiscal Year Series Report. No other data are known at comparable levels of reporting. The time period for which data are available spans the total life of the FMS and MAP programs. These data are considered to be both complete and accurate.

Sixteen years of data are available within DSAA history files which detail the transactions which aggregate to total dollar sales and deliveries. These files include information on cases, case loads, and the specific numbers of commodity items ordered and delivered by Service. These data are also considered accurate since the file is a subset of the total 30-year data base.

Manpower data are contained only within the SAMAS data base. Manpower data have been reported in detail for only 3 years. It is difficult to judge the accuracy of the data but SAMAS is all that is available and represents the official position of the Services with respect to security assistance manpower.

The sales and deliveries data used in this program to represent the independent variables are generally accurate and contain sufficient detail to consider multiple levels of aggregation.

- 30 years of program data at the highest levels of aggregation are adequate.

- 16 years of program data at lesser levels of aggregation are only marginal.

The manpower data available to this program to represent the dependent variables must be accepted as reasonably accurate.

- 3 years of manpower data at any level of aggregation are grossly inadequate.

2.7.2 Data Applicability

Work to date has considered the dollar volume of sales and deliveries to be the basic measure of FMS-MAP activity. Typically,

measures of work are stated in terms other than dollars. Thus, the relationships we are developing are at a different level than the cause and effect models which use work factors.

There are methods available to develop a relationship between dollar volume and work factor. The usual method is to divide the dollar value by the number of units involved and use the imputed value. When that is done, a forecast of dollars can be made and converted to units of work. In this case, there are many commodities involved. Within each commodity, there are many items. The possibility of computing directly an average value of dollars per a commodity into a work unit or work factor depends upon an assumption of a constant item-quantity mix over the time period of concern. This would be unlikely.

2.7.3 Exogenous Factors

The forecasting equations for manpower are based on the formulation of sales program projection equations using time series sales data. Exogenous events are not specifically identified nor are the dimensions of their effect considered. The basic philosophy is that such types of events will continue to occur at similar rates and with similar effects into the future. The validity of this assumption can be assessed only over time. At the moment, the data span may be inadequate to check the assumption.

2.7.4 Accuracy

The regression statistics which measure the accuracy of a sales projection are the first indication of error. The regression statistics which measure the accuracy of a deliveries projection are a second indication of error. The manpower forecast will be made using either the sales projection or a sales and deliveries projection. The regression statistics which measure the accuracy of the manpower forecast are the ultimate indication of error.

2.7.5 Confidence

Since there are a minimum of three steps in producing a *macro* manpower forecast, the manpower estimates are affected by at least three errors:

- The error in making the sales projection.

- The error in making the deliveries projection.

- The error in making the manpower forecast from the sales and deliveries projections.

The total error in a manpower projection then is the cumulative effect of the errors made in each step along the way.

2.7.6 Comparison

In deciding among forecasting alternatives, there is a clear requirement to minimize the difference between the data that are forecast and the actual data that are observed later.

- When a single regression relationship is used, the measure of utility is a coefficient of determination (r^2), which indicates the percentage of variation in the dependent variable explained by the regression equation.

- When more than one regression relationship is used, the requirement to minimize the errors applies to the entire process. This might result in the selection and use of alternative regression equations.

2.7.7 Results

The results of our test and validation activities are described in Section 3 following.

SECTION 3

TEST AND VALIDATION RESULTS

3.1 GENERAL

The contractual plan for Task 3, Test and Analysis of Alternative
Forecast Methods, requires that the results of our tests and analyses
be documented to include such details as: the nature, source, and
availability of data used; the sample size or similar statistical infor-
mation for each alternative tested; and the coefficient of determination
or other measures of accuracy/reliability obtained.

3.2 PROGRAM PROJECTIONS

In our Phase II report, we stressed the need for a suitable program
projection as a basis for a manpower forecast. Most logically, that pro-
jection would be developed and published by DSAA as future year program
guidance. The guidance should be reasonably accurate, should be coor-
dinated with the Department of State, and should provide a sufficiently
definitive basis on which the Service and Agencies can forecast and pro-
gram their future year manpower requirements. The ultimate importance
of a valid and useful program projection was confirmed in the Service
comments to our Phase II report and then affirmed by OASD(MRA&L) on
6 June 1980. Accordingly, the major part of our test and validation ac-
tivities to date have concentrated on the establishment of methodologies
for making program projections with a high order of accuracy, validity,
and utility.

3.2.1 Program Guidance

Rather than let the available data lead us into a form of possible
program projection, we examined, in some detail:

- The kinds of program guidance now provided to the Services
  (where, when, and in what detail).

- The kinds of program guidance now desired by the Services
  (where, when, and in what detail).

From these detailed reviews, both of guidance documents and of Service requirements, we have concluded that the basic program guidance for security assistance programs should be provided in the Consolidated Guidance. It is published annually to set the strategic objectives of DoD over the five-year period beyond the Budget Year. The program guidance should provide the level of security assistance sales activity by Service or Agency in terms of the five strategic geographic regions of interest in the Consolidated Guidance. Figure 3.1 is an example of form and content for the security assistance program guidance to be provided.

This level and form of program guidance will satisfy the requirement for the security assistance program to be responsive to and in support of the overall DoD strategy for the period. It could also satisfy the Service requirement to use a *macro* method of manpower forecast. It will not satisfy the Service requirement for sufficient guidance on which to develop a manpower program in support of security assistance activities. At least one additional level of program guidance is required. The additional guidance could also be published in the Consolidated Guidance. More likely, it would be developed for and published in the annual Administrative Budget Call issued by DSAA directly to the Services. This guidance should probably address each Service's security assistance program in terms of a sales program (in $); a deliveries program (in $); and a case program (in # of cases) for each commodity group within the Service program. Figure 3.2 is an example of form and content of the security assistance program guidance to be provided to each Service and Agency.

This level and form of program guidance would satisfy the basic requirement for detail necessary for the Service to develop its own estimate of specific workload and the related manpower requirements using either *intermediate* or *micro* methods for the manpower forecast.

<u>FY 1983</u>

<u>SECURITY ASSISTANCE SALES PROGRAM</u>
<u>(in $ millions)</u>

	DEFENSE	ARMY	NAVY	AIR FORCE	OTHER
TOTAL PROGRAM	XXXX	XXX	XXX	XXX	XXX
WESTERN EUROPE AND NATO	XXX	XXX	XXX	XXX	XXX
NEAR EAST AND SOUTH ASIA	XXX	XXX	XXX	XXX	XXX
EAST ASIA AND PACIFIC	XXX	XXX	XXX	XXX	XXX
LATIN AMERICA	XXX	XXX	XXX	XXX	XXX
AFRICA	XXX	XXX	XXX	XXX	XXX

Figure 3.1. Consolidated Guidance

<u>FY 1983</u>

<u>SECURITY ASSISTANCE PROGRAM - ARMY</u>

<u>COMMODITY GROUP</u>	<u>SALES ($)</u>	<u>DELIVERIES ($)</u>	<u>CASES (#)</u>
AIRCRAFT	XXX	XXX	XXX
* * *			
COMBAT VEHICLES	XXX	XXX	XXX
* * *			
TRAINING	XXX	XXX	XXX
TOTAL			

Figure 3.2. Service Guidance

3.2.2 <u>Program Data Characteristics</u>

We have found many differences in time series characteristics at various levels of disaggregation:

- The total security assistance (FMS + MAP combined) time series displays two major cycles. The first cycle is of ~22 years duration and is complete. The second is of only ~8 years duration and is incomplete.

- Each country group time series displays discrete but different sales cycles. In fact, the country groups (except "Western Europe and NATO") indicate only one cycle and these at dissimilar times between country groups. The "Western Europe and NATO" country group displays two cycles similar to the total program.

- Individual country time series often show zero sales volumes at various times. Typically, fewer than 20 countries (of about 75 countries in each annual program) account for at least 90% of the total dollar (FMS + MAP combined) sales in each annual program.

- Service time series display multiple cycles which differ in time phasing among the Services.

- Commodity group time series display cycles different than those seen in either the country group or the Service time series.

The best forecast methods for one level of aggregation did not always suit another. Thus, because sales forecast equations developed and tested for various levels of aggregation took two different forms, forecast equations were defined for each change of component or level of aggregation (i.e., Service, countries, commodities within either a country group or a commodity group).

3.2.3 <u>Program Projection (Sales)</u>

Program projections have been made for the total volume of sales at several levels of aggregation:

- Total Security Assistance programs
- FMS program
- MAP program
- Country Group program
- Service program
- Commodity Group program

Sales projections are based on the regression of dollar sales volume over time and the regression equations take two forms:

- A logarithmic-exponential form
- A cumulative sales form

Total sales projections are based on the existence of two cycles within the period 1950-1979, each cycle of ~22 years duration. On this basis, the data from 1973 onward were forecast based on the form of the equations derived from the data base 1950-1972.

The Hoerl's Special Function, a logarithmic-exponential form of projection equation, considers the data in three periods:

- A buildup and partial decay, 1951-1960
- A period of decay, 1961-1970
- A buildup and partial decay, 1971-1979

The Hoerl's Special Function equation takes the form:

$$\log \text{Sales} = \log a_1 + b_1(\log \text{Time}) + c_1(\text{Time})$$

Figure 3.3 is a plot of actual FMS and MAP sales experience in constant dollars for the period 1951-1979 against a forecast of sales over that period using Hoerl's Special Function with constants derived from regression analysis in three phases. The vertically shaded area is the difference between the actual and the Hoerl's forecast sales volumes.
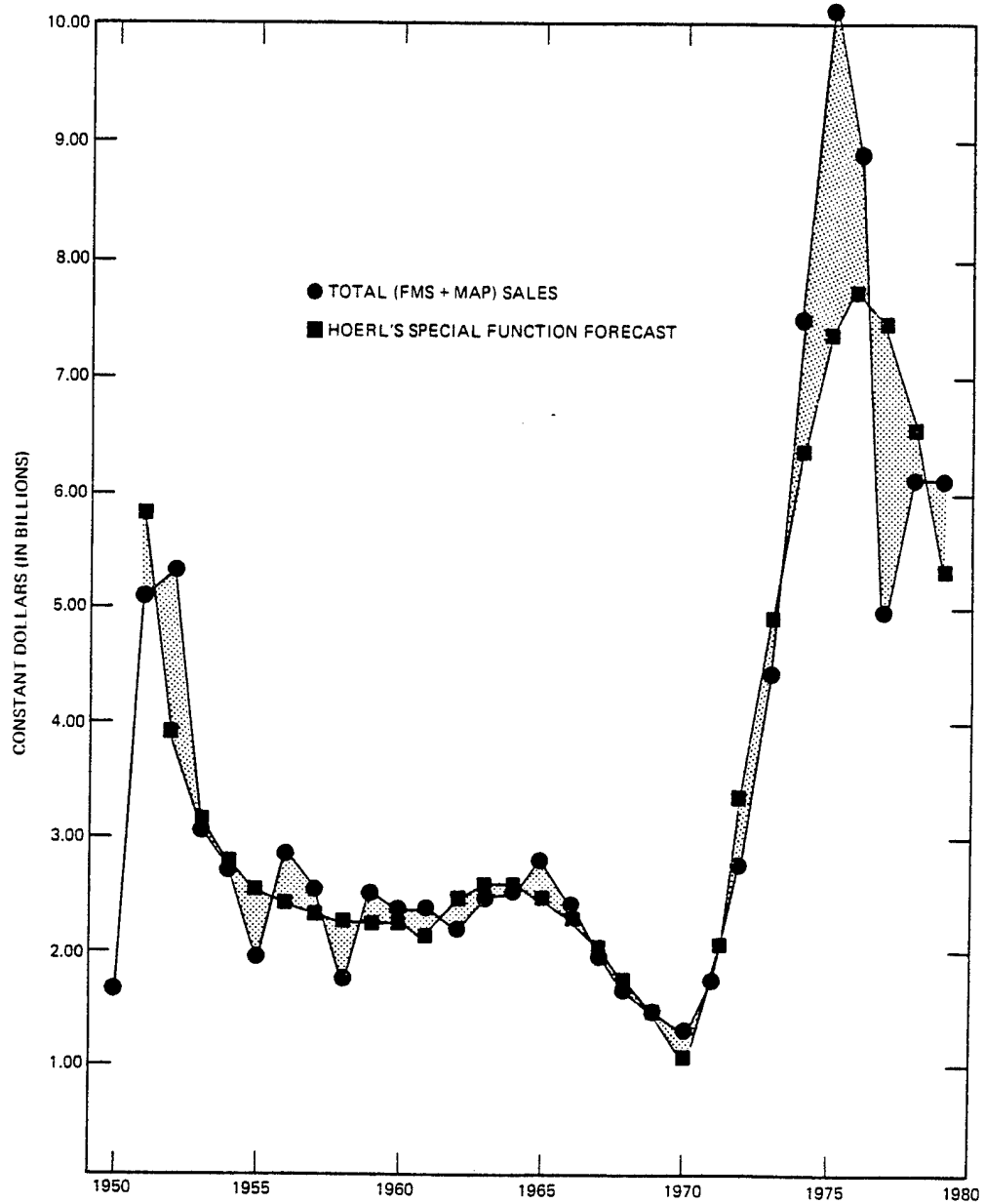
Figure 3.3 Total Annual Sales (Actual) vs Total Annual Sales
(Forecast), 1950-1979. (Using the Hoerl's Special Function)

Hoerl's regression statistics for the three periods were:

- 1950-1959 - coefficient of determination = .75; standard error in Sales = 691 million ($\sim$23% of the average yearly sales program)

- 1960-1969 - coefficient of determination = .863; standard error in Sales = 221 million ($\sim$9.9% of the average yearly sales program)

- 1970-1979 - coefficient of determination = .8995; standard error in Sales = 1,592 million ($\sim$29% of the average yearly sales program)

The cumulative equation form of program projection considers the data in only two periods:

- A complete cycle, 1951-1973
- An incomplete cycle, 1974-1979

The cumulative equation takes the form:

$$\text{Cumulative Sales} = a_1 + b_1(\text{Time})$$

Figure 3.4 is a plot of actual FMS and MAP sales experience in constant dollars for the period 1951-1979 against a forecast of sales over that period using the cumulative sales model regressed in two periods. The horizontally shaded area is the difference between the actual experience and the cumulative sales model forecasts. For the cumulative sales equation, the regression statistics for the two periods were:

- 1950-1972 - coefficient of determination = .98819; standard error in Sales = 1,810 million ($\sim$3.2% of the cumulative sales over the period)

- 1973-1979 - coefficient of determination = .98739; standard error in Sales = 1,960 million ($\sim$4.1% of the cumulative sales over the period)
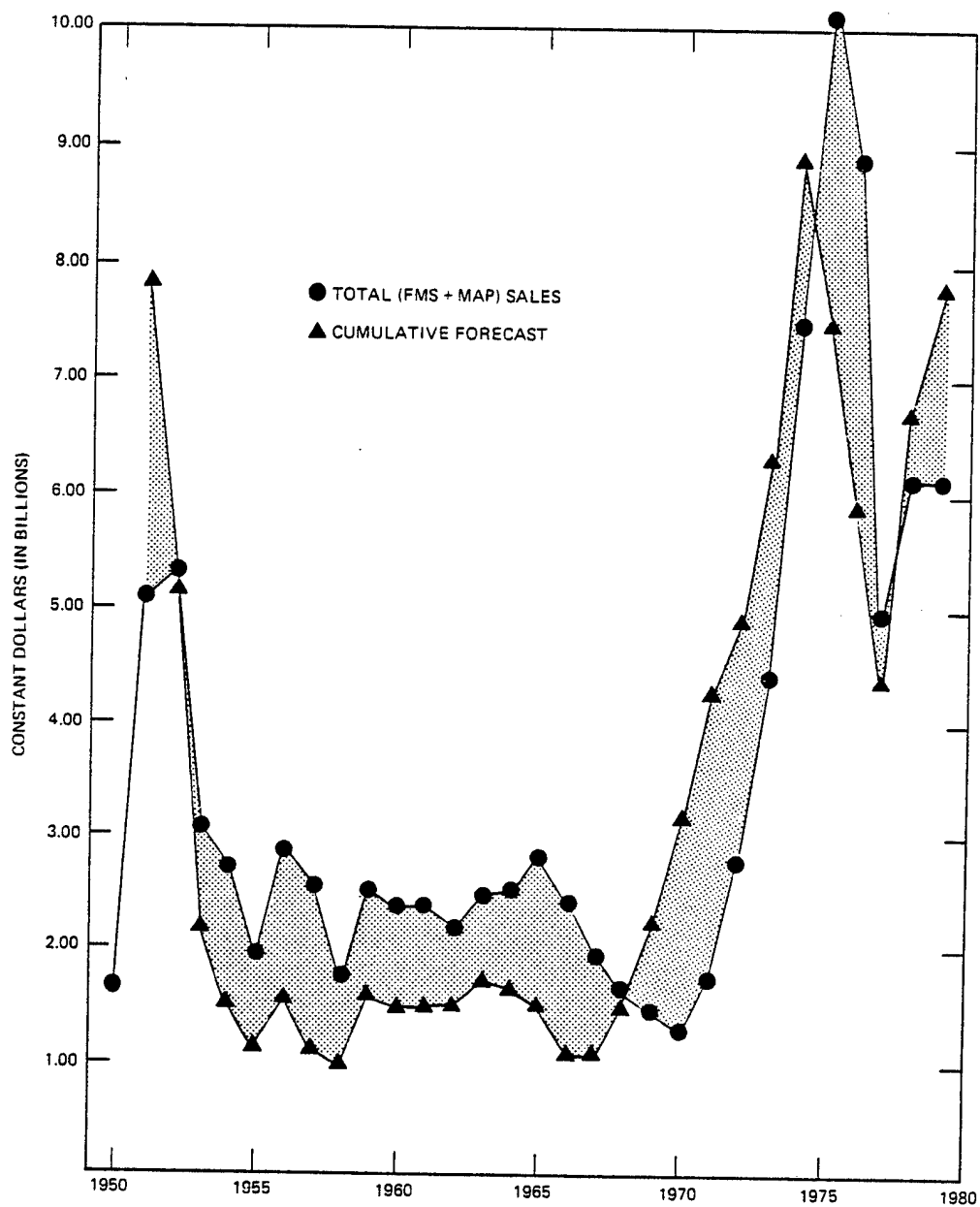
Figure 3.4 Total Sales (Actual) vs Total Sales (Forecast),
1950-1979. Cumulative Method.

3-8

A comparison of the plots provided by Hoerl's and the cumulative sales model reveals the following:

- The cumulative sales model follows the form of the cumulative sales experience well, but the individual yearly sales values obtained using the model have considerable difference from actual values.

- The Hoerl's approximation, because it is a smoothed model, provides less difference between projected and observed yearly values of sales, but does not reproduce the sales curve in as much detail as does the cumulative sum model.

For the purpose of projecting absolute dollar yearly sales, the Hoerl's approximation appears better than the cumulative sum model. For obtaining trends and cumulative values against which to adjust the smoothed Hoerl's estimates, the cumulative model is best.[1]

Details of these regression analyses for the total program portion of the program projection activity are in Appendix A.

Figure 3.5 is a plot of the cumulative FMS and MAP sales experience in constant dollars for the 16-year period 1964-1979 for the Western Europe and NATO country group. Constants were derived from two separate regressions: the first for 1964-1972; the second for 1973-1979. Again, the shaded area represents the difference between actual sales history and the forecast of sales. For the regression period 1964-1972, the coefficient of determination was .98277 and the standard error was 300 million ($\sim$3.7% of the cumulative sales over the period). For the regression period 1973-1979, the coefficient of determination was .94036 and the standard error was 966 million ($\sim$9.5% of the cumulative sales over the period).

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[1]The cumulative model is analogous to a "trend line" in "classical decomposition"; the Hoerl's model is analogous to a "cyclic" or "repetitive variation" from the trend line.
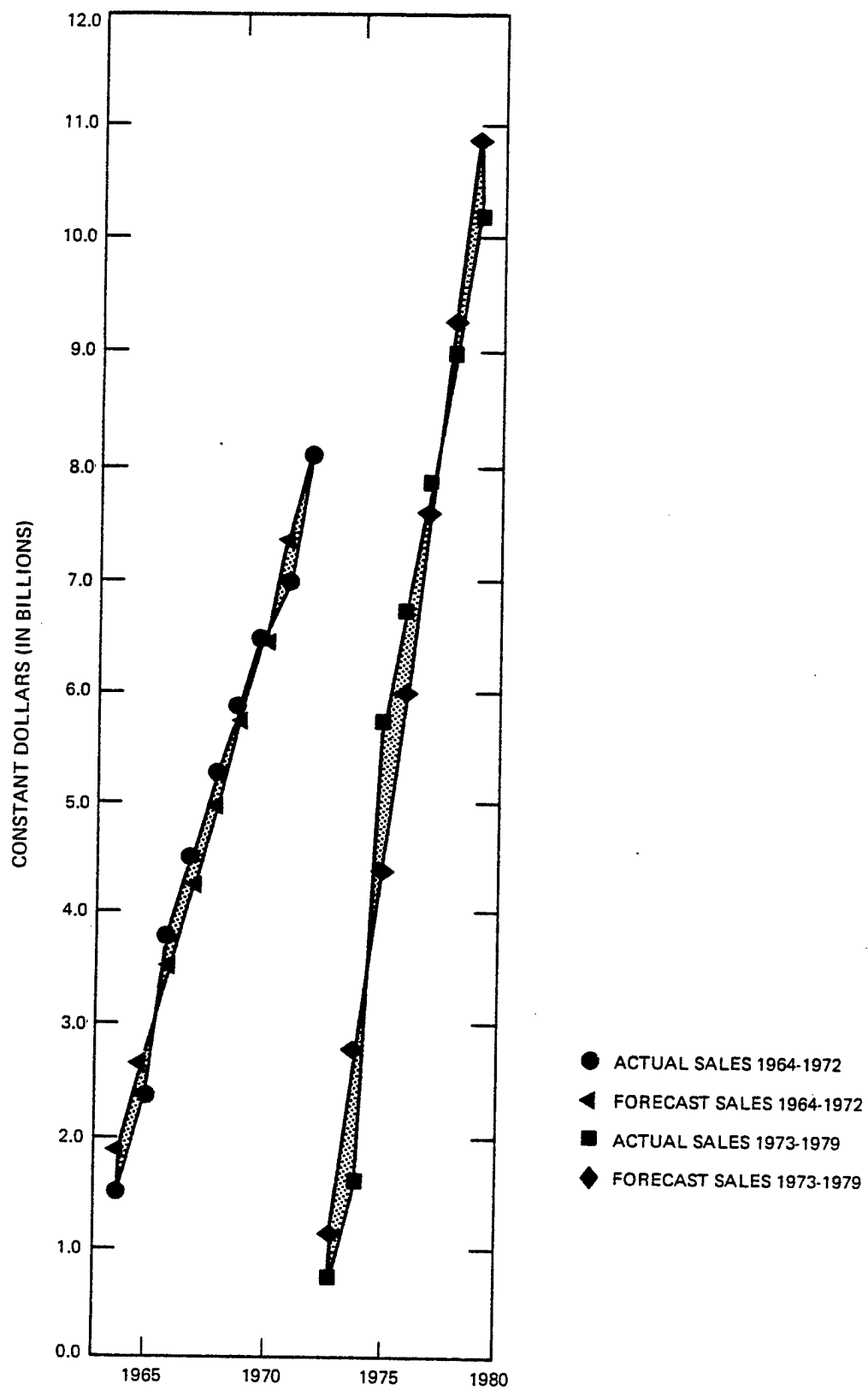
Figure 3.5   Cumulative Actual Sales vs Cumulative Forecast Sales
Western Europe and NATO Country Group

Details of these regression analyses as well as regression statistics and plots for all country groups are in Appendix B.

Figure 3.6 is a plot of cumulative Army FMS and MAP total sales experience in constant dollars for the period 1964-1979 against the forecast of FMS and MAP sales. Constants were derived from two separate regressions. Once again, the shaded area represents the differences between the forecast and actual experience. For the regression period 1964-1972, the coefficient of determination was .9929 and the standard error was 133 million ($\sim$2.6% of the cumulative sales over the period). For the regression period 1973-1979, the coefficient of determination was .9747 and the standard error was 1,140 million ($\sim$6.2% of the cumulative sales over the period).

Details of these regressions for the Army and the regression statistics and plots for all other Services are in Appendix C.

Details of the regressions for Commodity Group and the regression statistics and plots are in Appendix C.

3.2.4 Program Projection (Deliveries)

Program projections have also been made for the total security assistance deliveries. Total deliveries projections are based either on the existence of two distinct deliveries cycles within the 30-year period or on a derived relationship between sales and deliveries.

Deliveries projections, based on the regression of dollar deliveries volume over time, take a logarithmic-exponential form:

$$\log \text{Deliveries} = \log a_1 + b_1 (\log \text{Time}) + c_1 (\text{Time})$$

Deliveries projections, based on the sales projections, use a model in the form:
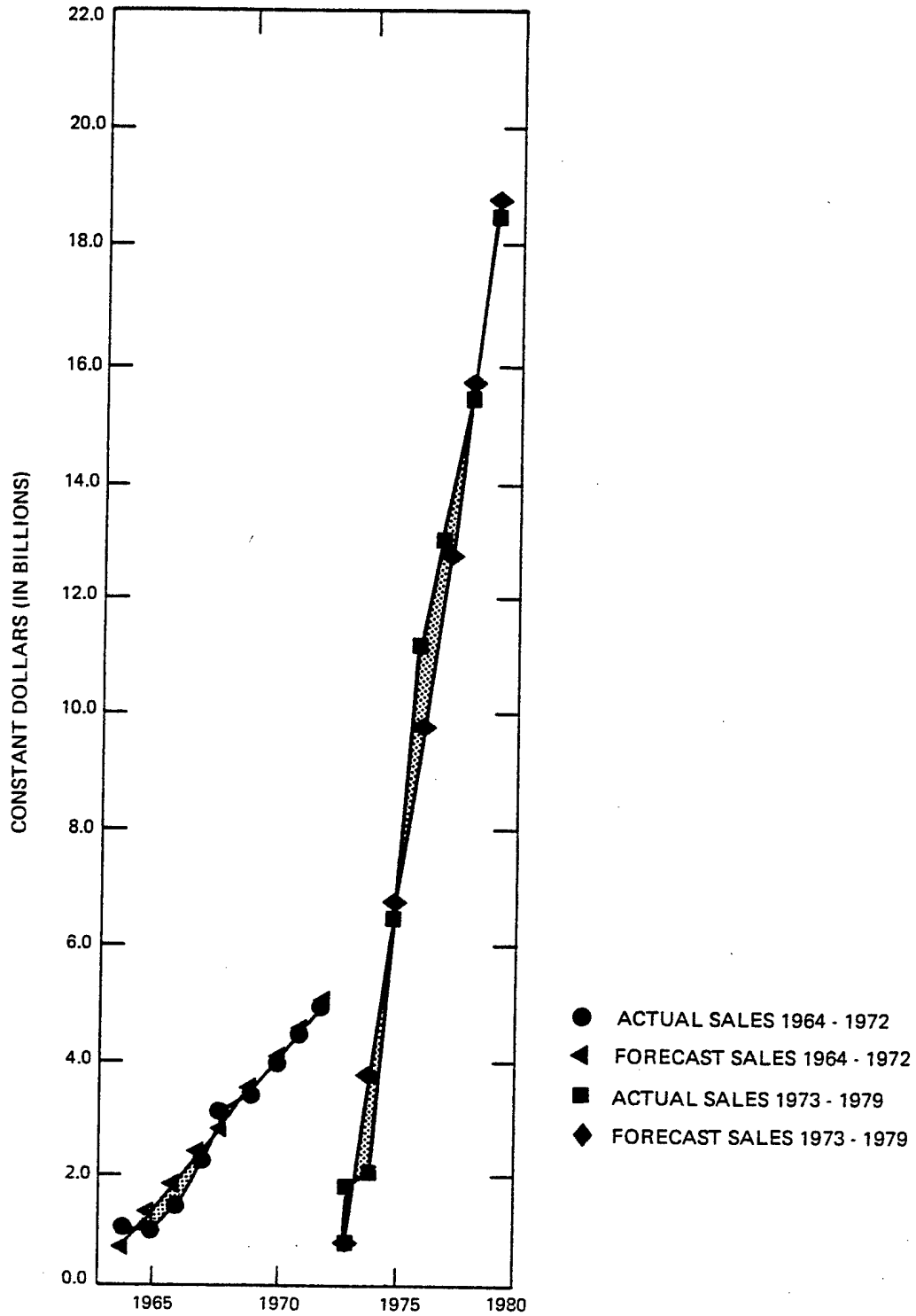
Figure 3.6 Cumulative Actual Sales vs Cumulative Forecast Sales – Army

The chart shows CONSTANT DOLLARS (IN BILLIONS) on the y-axis (0.0 to 22.0) versus years on the x-axis (1965 to 1980).

Legend:
- ● ACTUAL SALES 1964 - 1972
- ◀ FORECAST SALES 1964 - 1972
- ■ ACTUAL SALES 1973 - 1979
- ◆ FORECAST SALES 1973 - 1979

$$\text{Deliveries}_{(\text{year } i)} = a_1 + b_1(\text{Sales})_{(\text{year } i)} + c_1(\text{Sales})_{(\text{year } i-1)}$$

$$+ d_1(\text{Sales})_{(\text{year } i-2)} + e_1(\text{Sales})_{(\text{year } i-3)} + f_1(\text{Sales})_{(\text{year } i-4)}$$

Figure 3.7 is a plot of total FMS and MAP deliveries in constant dollars against a forecast of deliveries using this model. The 1950-1979 time period was divided into two cycles, and regression analyses were performed for each cycle. Once more, the shaded areas show the difference between forecast deliveries and actual deliveries experience. For the first period, the coefficient of determination was .785 and the standard error was 520 thousand ($\sim$23% of the average yearly deliveries. For the second period, the coefficient of determination was .9577, and the standard error was 318 thousand ($\sim$11% of average yearly deliveries).

Details of the regression and plots of the deliveries are in Appendix E.

To date, deliveries can be forecast with confidence for the overall deliveries program. The application of these equations to disaggregated data sets has not yet been validated.

Figure 3.8 is a plot of actual Sales and Deliveries over the 30-year period and a projection of Sales and Deliveries to 1983 using the Hoerl's Special Function method for sales[1] and the cause and effect model for deliveries.

3.3 A MACRO METHOD OF MANPOWER FORECAST

3.3.1 Program Projection

Conceptually, a gross or *macro* method of manpower forecast might be based on the establishment of a functional relationship of: total sales

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[1] The relationship between the cyclical component of sales (obtained using Hoerl's) was adjusted to conform to the trend line (derived using the cumulative method).
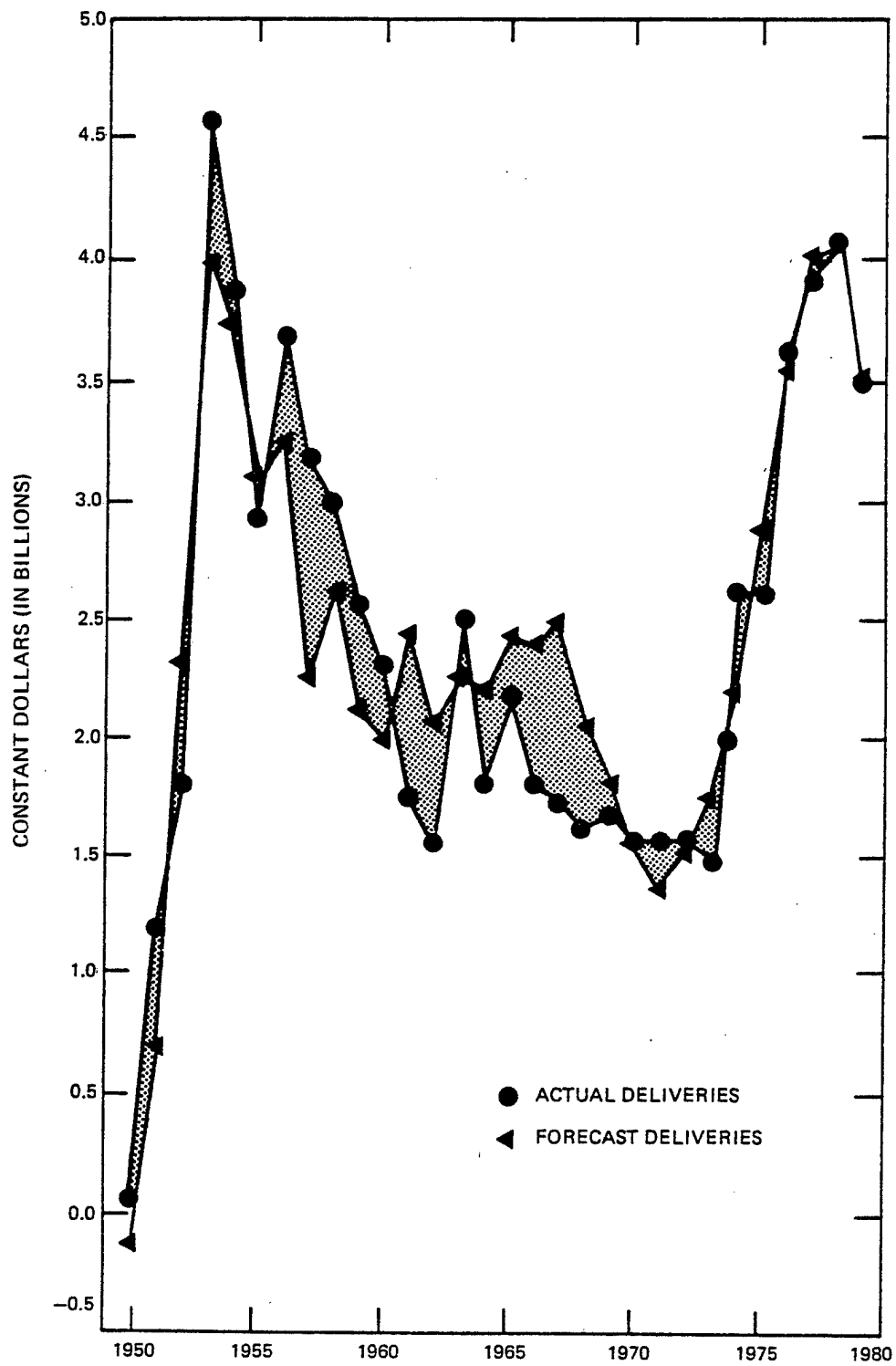
Figure 3.7   Total Annual Deliveries (actual)
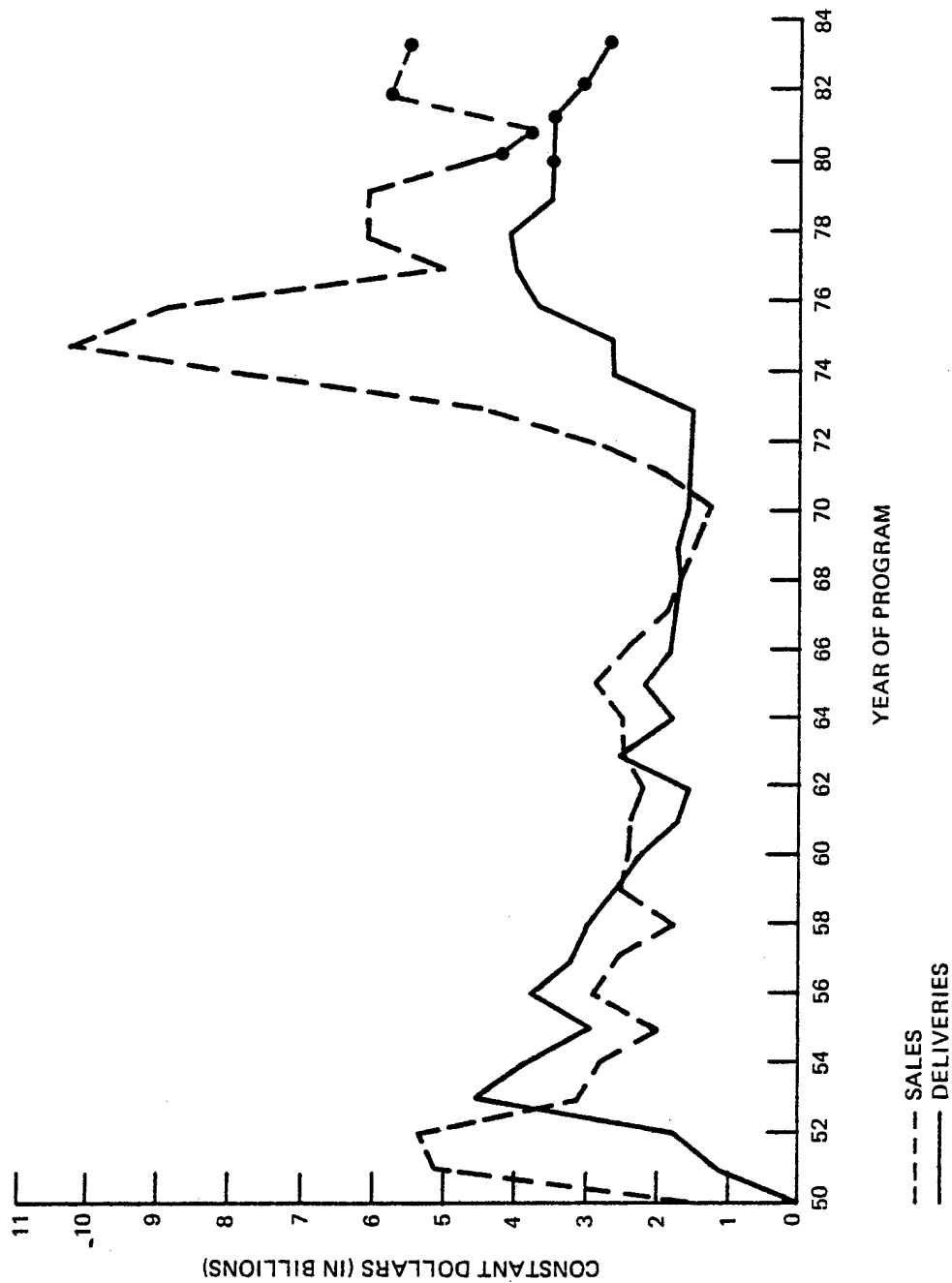vs Total Annual Deliveries (forecast),
1950-1979

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Figure 3.8 Security Assistance Sales and Deliveries, 1950-1979 projected through 1983

to total manpower; or, total deliveries to total manpower; or, total
cases to total manpower. On the assumption that sales or number of cases
probably drive the administrative manpower (about half) and deliveries
probably drive the remainder (about half) we performed a number of regres-
sion experiments. Ultimately, we established a reasonable and useful
relationship between total sales and total deliveries. The generalized
equation takes the form (1):

$$(1) \quad D_{83} = f(S_{83}) + f(S_{82}) + f(S_{81}) + f(S_{80}) + f(S_{79})$$

This relationship varies somewhat from Service to Service, from
country to country, and from commodity to commodity. But, for a *macro*
method (Total program to Total manpower) this relationship is valid.

We then performed a number of other experiments to determine the
relationship between total manpower (M) and the levels of total sales (S)
and total deliveries (D). We again established a reasonable and useful
relationship which takes the form of generalized equation (2):

$$(2) \quad M_{83} = a + b(S_{83}) + c(D_{83})$$

Finally, since deliveries (D) in any year are a function of sales
(S) in that year and sales in a number of preceding years, we substituted
the relationship between sales and deliveries developed in equation (1)

$$(3) \quad M_{83} = a + b(S_{83}) + c[f_1(S_{83}) + f_2(S_{82}) + f_3(S_{81})$$
$$+ f_4(S_{80}) + f_5(S_{79})]$$

3.3.2 Manpower Forecasts

Attempts to produce a *macro* method for manpower forecasting are severely limited by the data available in the SAMAS reports. The total SAMAS data are summarized in Figure 3.9.

Date of Report	1977 MY	1978 MY	1979 MY	1980 MY	1981 MY	1982 MY
3/30/78	21843	24565	25406	25694	-	-
4/18/78	21758	24566	25432	25787	-	-
1/25/79			29621	29709	29469	-
5/31/79			28453	26900	26670	-
11/16/79			25741	24552	24208	22909
1/14/80			23049	23507	22741	22283

Figure 3.9. Security Assistance Manpower (in man-years)

Only 3 years of actual and 3 years of estimated data are available. Three sets of manpower data were formed:

- A set of forecast man-years data which represent the Service estimates of manpower requirements.

- A set of data of 3 years' actual reported manpower and 3 years of "average" estimated manpower requirements.[1]

- A set of 3 years of actual data and 3 years of "latest" estimate.

---

[1] The estimated man-years for each year were averaged: for 1981, four estimated man-year values were added together and the sum divided by four.

The three sets of data were used to derive sets of regression constraints in the equation:

$$\text{Manpower} = a_1 + b_1 \text{ (Sales)} + c_1 \text{ (Deliveries)}$$

In the actual regression test, the coefficient of determination was 1.0 and the standard error was .0135 man years. These values describe a perfect fit between the data and the tested equation. Appendix F details the manpower, sales, and deliveries data used in this regression.

3.3.3 Forecast Accuracy

From these regressions, it can be seen that although the coefficient of determination of the regression is remarkably high (1.0), there is a wide variation in the regression constants obtained for each data set. Clearly, these attempts indicate that even though the form of the regression equation is likely to be correct, there is insufficient data to make a believable forecast.

There appears to be some utility in the *macro* forecasting technique if and when enough years of manpower data are available to develop a predirective equation. For the present, however, we believe it to have only limited value. Perhaps its main use will be to provide bounds to check manpower totals against the incremental manpower subtotals forecast by other methodologies.

3.4 INTERMEDIATE METHODS OF MANPOWER FORECASTS

3.4.1 Program Projection (Sales and Deliveries by Commodity)

Intermediate manpower forecasting methodologies can be based on the projection of service/commodity sales and deliveries programs in combination with a work unit conversion.

Using SAMAS data:

- We can apportion the total manpower of a Service among its organizational elements.

- We can associate the activity of each organizational element with a particular commodity set.

- We can project the sales and deliveries of that commodity set to develop the manpower forecasting methodology.

3.4.2 Manpower Forecasts

At the subordinate command levels, manpower requirements appear to be quite dependent on workloads. While a statistical model of the manpower associated with commodity sales may indicate a gross or average level of manpower requirement, the determination of the direct case and administrative manpower requirements would be better made using a cause and effect (or workload) model.

As a first test, we will regress the Army sales and deliveries against Army manpower. Then, we will regress Army commodity sales and deliveries against Army manpower levels within the commands with major responsibilities for sales and deliveries of the commodities.

3.5   A MICRO METHOD OF MANPOWER FORECAST

3.5.1 Program Projection (Workload)

Micro manpower forecasting requires a cause and effect relationship between workload and manpower. It assumes that a manpower loading equation can be developed to permit an estimate of manpower based on an estimate of workload.

- The Air Force uses estimating equations routinely. For example, the Air Force Logistics Command (AFLC) MANSAP model provides estimating equations for manpower requirements based on total requisitions anticipated as modified by probable country sales.

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- The Army Logistic Center has developed a simulation model (LOGCTR) which forecasts administrative manpower based on a series of estimated workloads which are generated sequentially. Workloads consist of LORs, LOOs, LOAs, requisitions, billings, number of cases, and number of lines.

Comparisons between the Air Force and Army models reveal considerable difference between the workload details necessary to exercise the models. We will review the existing DSAA LOR data files to determine how much detail is available to support workload forecasts at various levels. The steps in our analysis will be as follows:

- The total LOR file will be used to derive total file statistics by year: the number of LORs initiated each month during the years; the number of LOOs outstanding each month during the year; the number of LOAs outstanding each month during the year.

- LORs, LOOs, and LOAs will be categorized by Service, commodity, and country. The total number of dollars represented by all LOR, LOO, LOA, and the number of items represented by those dollars will be associated with each LOR, LOO, and LOA.

- Individual LORs will be tracked to determine the probability that:

  an LOR becomes an LOO;
  an LOO becomes an LOA;
  an LOR becomes an LOA.

The association of Service/commodity/number of items, and the total dollar value will permit development of a four dimensional probability distribution function and the computation of dollar value commodity mix ranges. All of these probabilities will have a time dimension. That is, the length of time it takes for each transition step to occur will be used to stratify the transition probabilities.

- Loading curves will be developed for Service/commodity groups on a monthly basis (and aggregated upward). These loadings will detail the number of active cases at each point in time. The number of active cases will be further subdivided into the number of LORs, LOOs, LOAs, and open cases from prior time periods.

- With loadings established, the Air Force MANSAP model and the Army LOGCTR model will be tested to determine how closely they have predicted the actual manpower data reported in the SAMAS. Since there are only three years of actual SAMAS data, however, the results of this test will be rather inconclusive.

Total sales and deliveries of each commodity will be used together with LOR and case load details to develop a series of probability density functions which describe mixes of workload in terms of the dollar values. The mixes then will form the basis for a simulation model which will forecast sets of workloads possible within the forecast range of dollar sales and deliveries. These forecasts, by subordinate command, will be aggregated and adjusted to be consistent with the Service totals.

3.6   PROGRAM PROJECTIONS

The results of our test and validation activities can best be demonstrated by producing some sample program projections.

Figure 3.10 is a 5-year forecast of the Security Assistance Program (in current dollars) as it might be developed for use in the Consolidated Guidance. Appendix G details the statistics and plots associated with this projection.

Figure 3.11 is a 5-year forecast of the Service Security Assistance Program (in current dollars) for Western Europe and NATO. Appendix H details the statistics and plots associated with this projection.

FCAST80

	1981	1982	1983	1984	1985
WESTERN EUROPE AND NATO	2.620847E+09	2.185856E+09	1.991548E+09	2.734365E+09	3.076644E+09
NEAR EAST SOUTH ASIA	4.100917E+09	8.236118E+09	7.052804E+09	7.724298E+09	6.377669E+09
EAST ASIA AND PACIFIC	1.334269E+09	1.499167E+09	2.094393E+09	1.200886E+09	1.159253E+09
AFRICA	3.882760E+08	2.984003E+08	2.087054E+08	3.201213E+08	3.721093E+08
LATIN AMERICA	2.343223E+08	2.255631E+08	1.072451E+08	8.558243E+07	7.580056E+07
ORGANIZATIONS	5.955761E+08	7.161306E+08	1.067500E+09	4.140516E+08	3.925640E+08
TOTAL PROGRAM	9.274204E+09	1.316123E+10	1.252221E+10	1.248010E+10	1.145404E+10

Figure 3.10   Total Security Assistance Sales Forecast by Strategic Geographical Region
(in current $)

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EURSVC80

	1981	1982	1983	1984	1985
ARMY FORECAST	6.337185E+08	6.806932E+08	5.590346E+08	6.136591E+08	8.951288E+08
NAVY FORECAST	1.172348E+09	8.472123E+08	3.255004E+08	1.501819E+09	1.691176E+09
AIR FORCE FORECAST	8.147807E+08	6.579502E+08	1.107014E+09	6.188877E+08	4.903391E+08
TOTAL SERVICE FORECAST FOR W.EUROPE AND NATO	2.620847E+09	2.185856E+09	1.991548E+09	2.734365E+09	3.076644E+09

Figure 3.11 Total Security Assistance Sales Forecast by Service for Western Europe and NATO (in current $)

SECTION 4

CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

4.1.1 Program Projections

We have successfully tested and validated a wide variety of program projection methods at various levels of aggregation. In the process, we have narrowed the choice of method to a selected few which can be developed and used with considerable confidence.

We conclude that the development of statistically based program projections should proceed as follows:

4.1.1.1 Program Projection (Sales)

● Examine the actual annual sales data set to:

- Develop the statistics[1] of the data.
- Compile the cumulative sum of sales data.
- Adjust the data to constant dollars.

● Use the cumulative sum of sales data to determine regression constants for a linear fit in the form of:

Cumulative Sales = a + b(Time)

● Compare the value of the regression constant b with the mean value of the data set.

- An exact correspondence between the two values indicates a perfect fit of the data set.

- A large deviation indicates the presence of some kind of long term variation (cycles or other similarities between subsets of the total data).

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[1] Maximum, mean, and minimum values, and the standard deviation.

- Plot the cumulative sum of sales data sets. Compare the plot of actual data to the plot of regressed data to see if the difference between the cumulative straight line regression and the actual cumulative data appears to be cyclical.[1]

- Determine the existence of cycles within the data by establishing the percents of trend or other relationships of the cyclical residuals.

- Define the characteristics of the cycles by testing for and computing the deviation (amplitudes) and frequency (duration).

- Regress the suspected cyclical data sets of the cumulative sales regression equation, one on the other. Use a regression equation in the form:

  Cumulative Sales X = a + b(cumulative Sales X1)

- Observe the degree of correlation obtained and measure the forecast accuracy by the coefficient of determination and the standard error.

- Make the Sales projection using the cumulative sales regression equation as modified to reflect the cyclical relationships between data sets. Pages H-46-51 of Volume II provides a description of the step by step procedure used to obtain the Army Sales projection for Western Europe and NATO.

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[1] The cumulative sum of sales regression is but one projection methodology to be examined. Other curve fits using different equations should be investigated as well. To do so, plots of yearly data and the cumulative data are required. The cumulative data plot smooths the yearly sales differences. Thus, deviations from the regression line can be tested to see if the difference forms a cycle (systematic deviations from the regression slope coefficient "b") or if the deviations form a random data set. The existence of cycles indicates that a curve fit might be found for the yearly data in the form of some cyclical curve such as the classical sine/cosine terms of the Fourier transform or the Hoerl's logarithmic-exponential construct properly applied to the data. The steps which follow determine which forms of equation should be tested.

4.1.1.2 Program Projection (Deliveries)

For a Deliveries projection based on the Deliveries history:

- Examine the actual annual deliveries data set to develop the data statistics and determine the existence of cycles.

- When cycles are clearly defined, test the cyclical data by regressing one set on another to verify that relationship.

- Use the data with an appropriate curve form and obtain regression constants for the cyclical deliveries data.

    - If the data continue to follow the logarithmic-exponential form, the equation is:

    $$\log \text{Deliveries} = \log a + b(\log \text{Time}) + c(\text{Time}).$$

- When all relationships have been determined, make the Deliveries projection using the logarithmic-exponential regression equation (if appropriate) to modify any other equation developed to reflect the regression relationships between cyclical data sets.

For a Deliveries projection based on a Sales projection:

- Regress the actual annual deliveries data set on the actual annual sales data set.

- Observe the relationships obtained and establish regression constants for a Deliveries/Sales model in the form:

    $$D_t = f(S_t) + f(S_{t-1}) + f(S_{t-2}) + f(S_{t-3}) + f(S_{t-4})$$

- When the regression provides a sufficiently high coefficient of determination and the regression constants are established, make the Deliveries projection using the developed equation.

4.1.1.3 Program Projections (General)

A technique remains to be developed to integrate each individual program projection with all other projections at various levels of aggregation to ensure that all program projections are consistent.

Each program projection produced must be subjected to expert examination for affirmation and/or revision because the projection methodologies rely on the observation of statistical cycles which appear to occur within the 30-year history of the FMS and MAP data bases.

As we gain experience with both the projection methods and the forecast equations established by our work to date and as we gain incremental additions of program history to the time series data base, confidence in the projected Sales and Deliveries programs made by these methods will grow.

4.2.3 Manpower Forecasts

In our Phase II report, we recommended that the test and validataion of a *macro* manpower forecasting methodology not be undertaken. However, comments by the Services indicated a desire to continue and complete the test and validation of a *macro* forecasting methodology. We have devoted considerable effort to the test of a *macro* forecasting methodology and conclude that the development of a *macro* method of manpower forecast, if desired, should proceed as follows:

- Examine the actual annual sales data set
- Examine the actual annual deliveries data set
- Examine the actual annual manpower data set

Regress the actual manpower data on actual sales and actual deliveries to determine the regression constants for a manpower forecast equation in the form:

$$M_t = a + b(S_t) + c(D_t)$$

If the regression produces a satisfactory coefficient of determination and standard error, use the manpower forecast equation developed for the year in question by inserting the projected Sales and Deliveries for that year to produce the Manpower forecast in man-years.

We conclude also that the three years of actual and three years of estimated manpower data available now within the SAMAS reporting system are inadequate. A manpower forecast developed using the gross relationships between the dollar volume of sales and deliveries and only three years of manpower history will fail.

The limitation of only three years manpower history data that militates so heavily against the utilization of a *macro* forecasting method also affects the other methods. Yet, in cases where estimating equations have already been developed to estimate manpower requirements based on work units, there appears to be a reasonable opportunity to develop manpower forecasting methodologies. We conclude that

- the potential to provide a useful *intermediate* forecasting method is rather high given the capability to relate projected dollar sales and work factor loadings.

- the potential to provide a useful *micro* forecasting method is high but will also rely heavily on the establishment of work factor loadings. We expect to forecast manpower using a *micro* method with at least the same accuracy as we forecast the work factor loadings.

In either case, the overall history to be used in the development of work factor/manpower requirement relationships is not limited to three years of SAMAS data. Rather, it will be based on the extensive survey and analysis work already done by the Services to develop manpower estimating procedures. If that work can be successfully integrated with the detailed sales and deliveries data to generate work factors, a firmly based set of forecasting methodologies seems possible.

We are vigorously pursuing the *intermediate* and *micro* forecasting methodologies and are optimistic that one or both will prove suitable as manpower forecasting tools.

4.1.3 Summation

Our test and validation efforts have been slowed significantly by a series of data processing delays. Nonetheless, considerable progress has been made and, so far, all results are positive.

- Usable procedures for program projection have been successfully established.

- Feasible procedures for *macro* manpower forecasting have been established (given a suitable historical data base).

- Prospects for the successful development of procedures for both *intermediate* and *micro* manpower forecasting are encouraging (based on our analysis to date).

4.2 RECOMMENDATIONS

4.2.1 Program Projections

We recommend that:

- No further test or validation of program projection methodologies be undertaken except as it is integral to the test of a manpower forecasting methodology.

- Test and validation of a linear or dynamic programing technique for integrating all individual program projections to ensure both consistency and simultaneity be undertaken after completion of this phase of the project.

- Test and validation of methodologies for replicating or simulating the life cycle of letters of request be continued and completed.

4.2.2 Manpower Forecasts

We recommend that:

- No further test or validation of a *macro* method for manpower forecasting be undertaken except as it is integral to any other test and validation activity.

- Test and validation of methods of establishing commodity/work factor/manpower relationships be continued and completed.

- Test and validation of *intermediate* methods for manpower forecasting based on established commodity/work factor/ manpower relationships be continued and completed.

- Test and validation of a *micro* method for manpower forecasting based on the LOR life cycle be continued and completed.

- Test and validation of a *micro* method for manpower forecasting based on Sales and Deliveries projections and work factor relationships be undertaken after completion of this phase of the project.

4.2.3 Other Recommendations

We recommend that:

- The final Study Documentation Report for this phase concentrate on specific recommendations for the selection of methodologies and the development of a program projection and manpower forecasting system.

- The development of selected and recommended methodologies be deferred until completion of the final Study Documentation Report for this phase.